U.S. Department of Agriculture Agricultural Research Service February 1993

Agricultural Research

Research Outlook Brightens at 1890 Schools

FORUM

ARS Plans Now for Future Scientists

Much has already been written about U.S. agriculture in the year 2000—how livestock might change, the role of biological control in battling pests and crop diseases, even the advent of unfamiliar but lucrative new crops on the American agricultural scene.

But here's an equally important question to consider: What will be the fate of U.S. agricultural research in the year 2000 and beyond?

We've known for some time that this country may be facing a shortage of agricultural scientists and engineers in the coming century—perhaps as many as half a million. According to the Task Force on Women, Minorities, and the Handicapped in Science and Technology, "A leaking educational and professional pipeline—from prekindergarten to Ph.D. and on through professional careers—is draining America's future."

But the potential talent is there, if we will only seek it out and nurture it. When the new century arrives, blacks and Hispanics, currently only 25 percent of all U.S. school children, will make up 47 percent of the total. By 2010, one in every three 18-year-olds will be black or Hispanic, compared to one in five in 1985.

Yet African Americans today make up only 2 percent of all employed scientists and engineers, even though they represent 12 percent of the nation's population. Only 4 percent of baccalaureate degrees in science and engineering—and only 1 percent of Ph.D's—are awarded to black students. Clearly this is a vast scientific resource that until recently has gone largely untapped.

In 1989, the U.S. Department of Agriculture began a concerted effort to change that picture through the 1890 Initiative. That's the name of a plan to encourage relationships between USDA agencies and the 1890 Schools, this nation's historically black land-grant colleges and universities.

Briefly, the history of 1890 Schools is this: In 1862, Congress passed the Morrill Act, which provided for the establishment of at least one land-grant institution in each state.

The legislation was flexible enough to allow for the establishment of a second land-grant institution for blacks if the states chose to do so. Mississippi did establish Alcorn State University for blacks in 1871, designating it as a land-grant school, and in Virginia, land-grant funds from the 1862 act were extended to blacks via Hampton University, a private institution.

A second Morrill Act, passed by Congress in 1890, provided additional endowment for the 1862 land-grant institutions. But it contained a provision that such funds would not be available to institutions that were practicing racial discrimination in admission. The result was the creation of many land-grant schools specifically for blacks, which came to be known as the 1890 Schools.

Agriculture and research have always been an integral part of the 1890 Schools. In fact, those institutions began under the same mandate as the 1862 schools: to provide instruction in agriculture, home economics, and mechanical industries. Additionally, research was part of the founding mission of the 1890 institutions.

In this issue of *Agricultural Research*, you will read how USDA—and specifically ARS—has worked hard to enhance research at today's historically black colleges and universities. Research payoffs are already being reaped, from new profit-making ideas for small farmers to advances in the war against animal diseases.

But beyond these individual victories, USDA is striving for a greater reward—harvesting the full value of our nation's scientific talents beyond the traditional circles. Investing time and money in cooperative research with the land-grant schools is a viable path to that goal.

How important is the link of the historically black schools in the educational chain? According to the National Science Foundation, of some 700 black men and women who received Ph.D.'s in science and engineering between 1986 and 1988, 29 percent earned their bachelor's degrees at black colleges.

And in some fields, the numbers are even higher: 42 percent of black Ph.D. biologists earned their bachelor's degrees at black schools. Our historically black colleges and universities are laying the foundation for many of the scientists and engineers that we will need for the coming years.

We know that not every student at an 1890 institution is going to pursue a career in agriculture or science. But enrollment is rising at the historically black colleges and universities—up 15 percent from 1986 to 1990, according to the National Center for Education Statistics.

Outreach programs such as BAYOU at Southern University in Baton Rouge, Louisiana, in which ARS is a major participant, enable us to give those students a glimpse of the possibilities of a career in agricultural research by bringing them into federal laboratories to work for the summer. And the student interest is certainly there: We have nearly 10 applications for every position available.

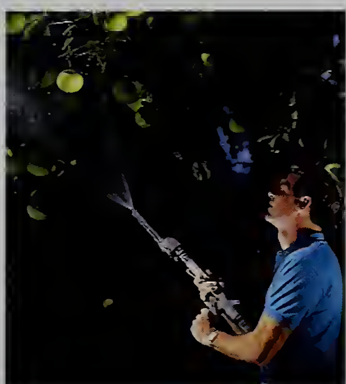
Other avenues of USDA cooperation, such as establishing a liaison on every 1890 campus and arranging for the schools to use equipment USDA no longer needs, give more than just a helping hand to these schools.

They represent a downpayment—and a sound investment—in the scientific leaders this country will need to maintain its world-class science and technical excellence in the 21st century.

William H. Tallent
Assistant Administrator
Agricultural Research Service

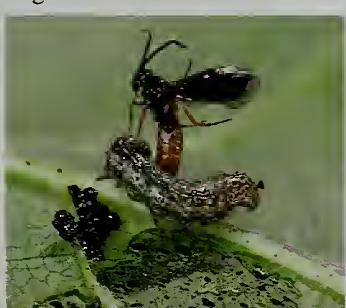
Agricultural Research

Cover: Delaware State College Career Enrichment Program students (L-R) Eric Coleman, Theodore Winsley, Sloane Smith, Rowena Kelley, George A. Jones, and Roland Ridgeway III, with research director Kenneth W. Bell (far right). Photo by Scott Bauer. (K5031-13)



Page 15

Page 19



Page 22

Vol. 41, No. 2
February 1993

Editor: Lloyd McLaughlin (301) 504-6280
Associate Editor: Linda McElreath (301) 504-6280
Art Director: William Johnson (301) 504-5559
Contributing Editor: Jeanne Wiggen (301) 504-6785
Photo Editor: John Kucharski (301) 504-5914
Assoc. Photo Editor: Anita Daniels (301) 504-5357

Agricultural Research is published monthly by the Agricultural Research Service, U.S. Department of Agriculture, Washington, DC 20250-2350. The Secretary of Agriculture has determined that publication of this periodical is necessary in the transaction of public business required by law.

Information in this magazine is public property and may be reprinted without permission. Non-copyrighted photos are available to mass media in color transparencies or black and white prints. Order by photo number and date of magazine issue.

This publication was printed with soybean oil-based inks.

Subscription requests should be placed with New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954. Please see back cover for order form.

When writing to request address changes or deletions, please include a recent address label.

Address magazine inquiries or comments to: The Editor, Information Staff, Room 316, Bldg. 005, 10300 Baltimore Ave., Beltsville Agricultural Research Center-West, Beltsville, MD 20705.

Mike Espy, Secretary
U.S. Department of Agriculture

R.D. Plowman, Administrator
Agricultural Research Service

Robert W. Norton, Director
Information Staff

ARS Helps Science Flourish at 1890 Schools

SCOTT BAUER

Research assistant Marita Smith and dean of agriculture Bobby Phills (from the left) instruct Southern University and A&M College agriculture students who are receiving scientific instrumentation training through a USDA summer hiring program. (K5033-16)

Bold ideas were brewing at the U.S. Department of Agriculture as America headed into the last decade of the 19th century.

Although the department had been created 28 years earlier by Abraham Lincoln, the year 1890 found USDA leaders still savoring the department's elevation to cabinet status only 1 year before.

At USDA's helm was agriculture secretary Jeremiah McLain Rusk, a Wisconsin farmer, Civil War hero, and strong believer in getting information to farmers. It was Rusk who pushed for the publication of informative Farmers Bulletins, first by USDA's Office of Experiment Stations and later by the department itself.

Also in 1890, there was an update to the 1862 Morrill Act, which provided for the establishment of at least one land-grant college in each state.

Although the Morrill Act of 1890 was passed to further fund those 1862 institutions, it contained a history-making provision: that states practicing racial discrimination in admissions to 1862 schools could not share in the additional funds provided by the 1890 act.

In many states, the direct result of that provision was the creation of separate land-grant schools for blacks. Several southern states either established a new school or took over an existing institution and designated it as a land-grant institution.

Seventeen institutions are now officially recognized as 1890 Schools—one in each of 15 states, plus two in Alabama. But 12 of these institutions actually predate the Morrill Act of 1890, and not all were established by their state legislatures.

For example, the first of the 1890 Schools, Lincoln University at Jefferson City, Missouri, was actually

founded in 1866 with funds from Civil War veterans.

Another, the University of Maryland-Eastern Shore, was founded in 1886 by the Methodist Episcopal Church.

Research has always been part of the mission of 1890 Schools, but fulfillment of that mission was often hindered by lack of money. Research funds usually went to the 1862 schools, although there were exceptions—the branch experiment station established in 1887 at Prairie View A&M University in Prairie View, Texas, for example, and the experiment station established at Tuskegee University in 1897.

As the 100th anniversary of the 1890 Morrill Act neared, the research outlook at the historically black land-grant institutions was considerably brighter. But there were those in USDA who felt the department could do more to help.

"In 1988, USDA began what is called the USDA/1890 Initiative," recalls Korona I. Prince, special programs manager in the office of Agricultural Research Service administrator R. Dean Plowman.

"The sole purpose of that initiative was to encourage a partnership between USDA and the 1890 Schools. It was initiated by USDA, beginning with a conference in Nashville, Tennessee, in 1988."

From that Nashville meeting, attended by 1890 School deans and presidents as well as USDA officials, was born a list of 17 action items.

These included sending USDA personnel—such as ARS researchers—to 1890 campuses to work on specific projects; establishment of USDA liaisons on each of the campuses; student outreach programs; and a Capacity-Building Grants Program.

"Under the latter program, schools submit grant proposals for important areas of research they'd like to do," says William H. Tallent, ARS assistant administrator. "The aim is for them to

The Morrill Act of 1890 contained a history-making provision: that states practicing racial discrimination in admissions to 1862 schools could not share in the additional funds provided by the 1890 act.

build their institutions' capacity to contribute to science."

Congress appropriates the money, which is administered by the Office of Higher Education Programs in USDA's Cooperative State Research Service.

In the first year of the program, which began October 1, 1989 (fiscal

KEN HAMMOND

Jeremiah McLain Rusk was Secretary at Agriculture when legislation creating the 1890 Schools was enacted. (K5063-1)

year 1990), Congress appropriated $5 million; 4 years later, for FY 1993, it was $10.25 million.

Each grant must have a cooperating USDA agency. Of the 22 research grants approved for funding in 1992, ARS was one of the cooperating agencies on 18, Tallent notes. "We work on everything from new crops to flavor components of goat's milk."

But Tallent points out the capacity-building grants—and even the 1890 Initiative of 1989—were not ARS' first encounter with 1890 Schools.

"We've had programs for years to encourage our scientists to work with 1890 Schools," he says. "Before the Capacity-Building Grants Program began, ARS had its own program, with about $500,000 in annual funding. We'd either conduct a research project with an 1890 School or sponsor a post-doctoral researcher on an 1890 campus."

Nor has ARS involvement been limited to the 17 traditional 1890 Schools.

"ARS has worked with many of the historically black colleges and universities—there's a total of 117 nationwide, including the Virgin Islands—since the 1970's," adds Prince.

Special Outreach Projects

Student outreach is another area where ARS involvement predates the 1890 Initiative of 1989.

In the Career Enrichment Program, dating to the early 1980's, high school seniors bound for Delaware State College at Dover first spend a summer working in ARS laboratories. That program is jointly sponsored by ARS and other USDA agencies working with the Delaware Cooperative Extension Service.

A similar program called BAYOU—for "Beginning Agriculture Youth Opportunity Unit"—involves not only incoming freshmen, but also college science students at Southern University at Baton Rouge, Louisiana.

In other outreach programs, students from the Chicago High School for Agricultural Sciences spend the summer on the campuses of Kentucky State and Tennessee State Universities and work in ARS labs. ARS and USDA's Soil Conservation Service fund that program.

"We do all this because we realize these students are our future," says Prince. "We need to get good students into agricultural sciences, and this is a way to do it."

In November 1992, USDA agency heads and 1890 institution presidents met to set new goals for the 1890 Initiative.

One of these was to establish centers of excellence—concentrations of expertise on particular agricultural subjects at each of the 1890 Schools.

"Within the next decade, we'd like to have a center of excellence on each of the 1890 campuses," says Tallent. "The universities tell us what they'd like to have a center on, and the various USDA agencies have the option to help.

"ARS is working with four or five proposals, seeking about half a million dollars for each. USDA will decide how many to go with overall and go to Congress for funding. The first year that may be funded is FY 1994."

SCOTT BAUER

Agriculture students Sally Alexander and Anthony Hadley test rice varieties for germination and seedling growth under drought and salinity stress at the University of Arkansas at Pine Bluff. (K5030-19)

Nursery Crop Production

Among the proposals supported by ARS is the creation of a nursery crop production center at McMinnville, Tennessee, as part of Tennessee State University.

"Tennessee State acquired 87 acres of land at McMinnville in the center of the nursery industry there," recalls Howard J. Brooks, ARS associate deputy administrator for plant sciences. "Nursery crops are a big business in Tennessee; producers there grow most of the ornamental trees and shrubs for the eastern seaboard."

The Tennessee State proposal calls for sending selected plant material from ARS' National Arboretum breeding program at Washington, D.C., to McMinnville.

"The arboretum, in its breeding program with landscape shrubs and trees, might have 10,000 seedlings," Brooks explains. "They would select several that look the best and send them to the center of excellence, where nursery specialists could help select the very best and recommend commercial production.

"ARS is helping with the design of a new laboratory and office building," he continues. "We're also working closely with Tennessee State personnel on the concept of how the program might be expanded over the years to include ARS personnel actually doing research at McMinnville."

KEITH WELLER

At Tallahassee, landscape design and management student Johnnene Addison helps sort aquatic insects to be used in biological monitoring of water quality. (K5038-1)

Separate from the centers of excellence proposal, ARS is already in the second year of a 3-year cooperative agreement with Tennessee State to develop a plan for evaluating nursery plant material in the area, Brooks notes.

"Our intent is to serve the entire U.S. nursery industry," he says. "If a new landscape plant would grow in Tennessee, it probably would do well in other states with similar climates."

Rice Growing Without Flooding

Another example of the ongoing association between ARS and 1890 Schools is the work done at the University of Arkansas at Pine Bluff. It involves evaluation of rice germplasm to find lines that would perform well in nonflooded fields—just like corn or wheat.

"In 1987, ARS had a pilot program for competitive grants for research with 1890 Schools," says Robert H. Dilday, a geneticist with the ARS Rice Production and Weed Control Research Unit at Stuttgart, Arkansas.

"Mazo Price of the University of Arkansas at Pine Bluff worked with me on a proposal for cooperative research to develop techniques for evaluating rice germplasm for drought tolerance. That project was subsequently funded for 1987 and 1988."

While the typical image of rice is that of lush green plants growing in

flooded fields, Dilday says rising cost and declining availability of irrigation water may push some rice crops of the future to dry land in certain areas of the United States.

"We've made rice into a very-high-input crop because it yields more if fields are flooded, plus flooding the fields is a very good way to control major dryland weeds such as morning-glory," he says. "But the fact is that 47 percent of the rice grown in the world is under natural rainfed conditions."

Price, Dilday's partner in the project, is now dean of the university's School of Agriculture and Home Economics, as well as director of 1890 research and extension programs at the university. But he spent the late 1970's and early 1980's in eastern Africa, working to develop varieties of crops such as pigeon peas, sorghum, and millet that could stand the trials of low soil fertility and scarce water.

"When I came back to the United States in 1986, I had the idea that we really needed to work on drought-tolerant crops in this country," says Price. "We have water now, but the time may come when it is lacking."

In 1987, with their funds from ARS, Dilday and Price evaluated 50 rice germplasm lines that had previously evidenced some drought tolerance or better use of available water. Some of the lines came from the International Rice Research Institute at Los Baños in the Philippines; others, from the U.S. rice collection containing more than 16,000 varieties from 99 countries.

The researchers used a long-known technique called root pulling resistance, which correlates the difficulty in pulling a plant from the ground with its degree of root development.

"We tried to relate root development to drought tolerance," says Dilday. "There is a relationship, but there are other factors as well—leaf size, leaf shape, the opening and closing of the leaf's stomates. We were the first to show this relationship in dry-seeded rice."

In the second year of the project, Dilday and Price used an Image Capture and Analysis System at the university to reveal differences in the visual image of drought-tolerant versus drought-sensitive rice lines.

"We've had this system for several years," says Price. "You take a video picture of plants in the field, bring it back to the lab, and hook it to a computer.

"On the basis of leaf color and factors such as the amount of light absorbed and reflected, this system can provide information on the plants' photosynthetic activity, as well as tell whether they have disease damage or other conditions.

"Once we get this system perfected in terms of screening for drought tolerance, it will be a much faster test than root pulling resistance. "

A Mystery Protozoan

Another ARS/1890 project involves the ARS Protozoan Diseases Laboratory at Beltsville, Maryland.

When word went out in 1987 that the agency had research funds available for cooperative work with 1890 Schools, ARS microbiologist Michael D. Ruff saw an opportunity to take a crack at solving a longtime mystery.

"There are nine species of single-celled organisms called coccidia that are listed as affecting chickens and causing a disease called coccidiosis," explains Ruff. "But one of them, *Eimiria mivati*, may not really exist."

Coccidiosis is bad news for poultry farmers, costing them some $300 million a year—$200 million in lost production, because birds don't grow as they should, and another $100 million for medications.

"When a new drug against coccidiosis comes along, the Food and Drug Administration requires that it be

SCOTT BAUER

Research assistant Marita Smith instructs Southern University student Wayne Spears in the operation of a digester used to determine the protein content of feed samples. (K5032-19)

SCOTT BAUER

◀ In an experiment to determine how well rice plants use water, University of Arkansas at Pine Bluff students Sally Alexander and Anthony Hadley measure yield and plant mass while assistant professor Mohammed Jalaludin (left) records the results.
(K5030-20)

▶ Landscape design student Bruce Thornton is working on a project to identify aflatoxin-resistant peanut lines at Florida A&M University in Tallahassee.
(K5040-1)

cleared against all the common species of coccidia, including *E. mivati*," explains Ruff. "But if *mivati* doesn't really exist, that's one less test to do.

On the other hand, Ruff adds, "if *mivati* does exist and we don't include protection against it in vaccines, it could have a significant impact on the poultry industry.

"Coccidia do not 'cross-protect.' If you vaccinate a chicken against one species of coccidia, the chicken's immune system protects it only from that species of coccidia—not against all the others as well."

When the ARS cooperative funds became available, Ruff joined forces with Steve Fitz-Coy of the poultry diseases department at the University of Maryland–Eastern Shore.

"Steve was at Princess Anne, Maryland, and had ready access to commercial poultry operations," explains Ruff. "He'd get cultures of coccidiosis, purify them, and send them to us for testing. He looked at several hundred cultures and from those, found two or three to send to us that looked promising."

SCOTT BAUER

Research assistant professor Bernard Petrosky points out the qualities of a pond-raised hybrid striped bass for Jean Staats, a student studying fisheries science at Delaware State University.
(K5034-17)

Once the cultures arrived at Beltsville, Ruff's lab did a variety of tests to determine if the culprit was *mivati*. For example, chickens were vaccinated against other species of coccidia, then infected with a possible *E. mivati*. Since the vaccination would protect against species other than *mivati*, the researchers knew that if the infection, stymied by the vaccination, failed to run its course, the culture in hand was not *mivati*.

"We've gotten several cultures that look close to what I knew as *mivati* 20 years ago," says Ruff. "I think there definitely was an *E. mivati* at one time."

Fitz-Coy has since left the UM–Eastern Shore faculty to work for American Cyanamid, but the project is continuing, Ruff reports.

"People in the field are sending us cultures to check," he says. "This is a good example of why we have cooperative work with 1890 Schools—

KEITH WELLER

we couldn't have started this as easily without Fitz-Coy sending us those original isolates."

Dairy Goats and Milk Products

"One aspect of the ARS initiative in 1987 was to establish a series of postdoctoral positions at 1890 Schools, working on campus and collaborating with ARS scientists," recalls Harold M. Farrell, Jr., a supervisory research chemist in the Biochemistry and Chemistry of Lipids Laboratory at the ARS Eastern Regional Research Center (ERRC) at Philadelphia, Pennsylvania.

"Alden Reine, who was then director of research at Prairie View A&M University in Prairie View, Texas, contacted John Cherry, the ERRC director. Prairie View had established an International Dairy Goat Center, wanting to carve a research niche for itself in dairy goat work. Reine knew that back in the 1980's, we had done some dairy goat milk research here."

Prairie View and ERRC later entered a cooperative research agreement and hired a postdoctoral researcher, Adela Mora-Gutierrez, who began working at Prairie View in May 1989 on casein in dairy goat milk.

"Casein is a major protein in milk," Farrell explains. "It keeps phosphate and calcium in the milk soluble so they can pass out of the udder. Without it, they'd become crystals—and that wouldn't make milk a very nice product to drink."

The scientific community had long held that casein in goat's milk and cow's milk was basically the same, with the exception of one protein missing from goat's milk.

Farrell says French scientists in recent years discovered that the elusive protein not only was present in goat's milk after all, but could differ from goat to goat in its ability to carry calcium and phosphate.

The ARS research team—Mora-Gutierrez at Prairie View, Farrell and others at Philadelphia—found that virtually all goats differ in their levels of alpha casein, the best of four major caseins in ability to carry calcium and phosphate.

"We found one goat that had about 30 percent as much as a cow," Farrell notes.

Much to their surprise, the scientists found that a goat could have very low alpha casein levels and still boast high calcium content in its milk.

"Also, we thought that if a goat's milk was missing alpha casein, which is great at carrying calcium, and you added calcium to the milk, it would just clot up," Farrell recalls. "But surprisingly, the exact reverse occurred. In processing, the high-alpha milk was more likely to clot up."

When Mora-Gutierrez's 2 years as an ARS postdoc wound up in 1991, she was hired immediately to continue research at Prairie View, much to the delight of her ARS co-workers.

Although the Prairie View research has uncovered surprising new information about goat's milk composition

and physical properties, the ARS/1890 collaboration there promises to yield even greater long-term rewards, says Mora-Gutierrez.

"I'll be teaching food chemistry, starting in 1993, as part of a new curriculum option in food science and nutrition at Prairie View. Our students will be able to say, "We have a research scientist right here on campus, and she is our professor." It will give motivation for our students to consider careers in agricultural research."

At the University of Arkansas at Pine Bluff, Mazo Price sees the ARS cooperation with 1890 Schools as an enrichment process for the universities.

"When we can draw on expertise like Robert Dilday's and transfer that knowledge to the university, it tremendously enhances our own ability to do research," he says.

"And I say if you enhance the research capability of a scientist, you make a better teacher of that scientist, so the benefits are passed on to our students. The students can come to the field and see the type of research we're doing, read the publications, and even participate in the research.

"Between us and ARS, I would argue that this type of cooperative effort benefits us more because it enhances significantly our capacity to provide quality research and teaching."—By **Sandy Miller Hays,** ARS.

For more information on ARS scientists mentioned in this article, contact Sandy Miller Hays, USDA-ARS Information Staff, Bldg. 419, 10300 Baltimore Ave, Beltsville, MD 20705-2350. Phone (301) 504-9089, fax number (301) 504-8030. ◆

1890 Historically Black Land-Grant Institutions

1866 - Lincoln University, Missouri
1871 - Alcorn University, Mississippi
1872 - South Carolina State University
1873 - University of Arkansas at Pine Bluff
1875 - Alabama A&M University
1876 - Prairie View A&M University, Texas
1880 - Southern University, Louisiana
1881 - Tuskegee University, Alabama
1882 - Virginia State University
1886 - Kentucky State University
1886 - University of Maryland–Eastern Shore
1887 - Florida A&M University
1891 - Delaware State College
1891 - North Carolina State University
1895 - Fort Valley State College, Georgia
1897 - Langston University, Oklahoma
1912 - Tennessee State University

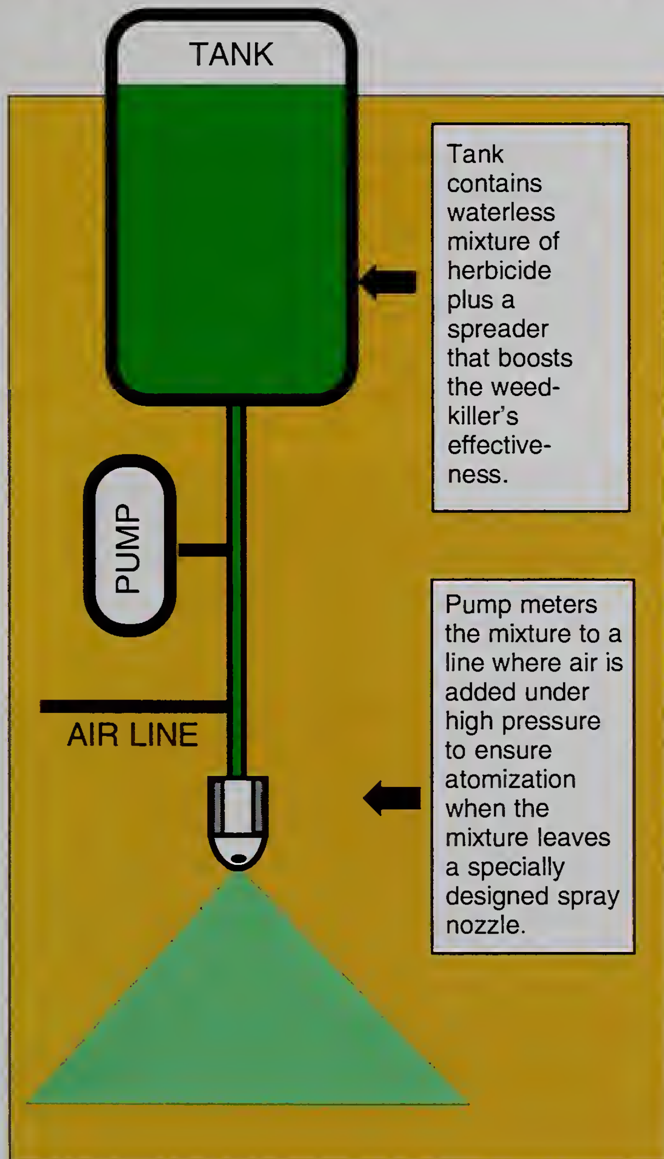
Although originally established to expressly meet the educational needs of African Americans, these colleges today provide instruction to widely diverse student bodies.

SCOTT BAUER

Professor Edward Jones discusses an alfalfa nutrition experiment with Delaware State College students (left to right) Tony Carney, Latisha Corey, and Karen Meyer. (K5034-16)

245

Farmer-Friendly Herbicide Applicator



How low can it go? That's the question Chester McWhorter and co-workers were asking themselves nearly a decade ago.

In 1983, McWhorter, an ARS plant physiologist at the Jamie Whitten Delta States Research Center, was searching for a way to reduce the amount of water that is mixed with herbicides used to kill weeds on agricultural lands. Typically, 5 to 20 gallons of water are used per acre.

"Hauling water to the field can be expensive and time consuming for farmers," explains McWhorter, now head of the Application Technology Research Unit at the Stoneville, Mississippi, center. "We thought cutting the amount of water in the herbicide mix would give us a substantial saving."

Each year the researchers cut back. Eventually, they decided to go for broke and eliminate all the water. The mix consisted of a herbicide and a spreader to boost the weed-killer's effectiveness. But when it came time to apply the herbicide at less than 1 gallon per acre—ultra low volume (ULV) application—they encountered problems with the spray equipment. Conventional hydraulic nozzles did not adequately distribute the spray.

So Floyd Fulgham, an agricultural engineer in the center's Field Mechanization Research Unit, developed an application system called the T-miser. Resembling an inverted "T," the nozzle uses air to atomize the herbicide mixture—instead of liquid pressure, like conventional hydraulic sprayers.

As research progressed, scientists found two problems with the sprayer: The holes in the disk were so tiny they became clogged, and the plastic tubing used as a nozzle orifice did not adequately distribute the spray in a swath.

To remedy the problems, Fulgham replaced the disk orifice, a round piece of metal with a hole in the middle, with a positive displacement, piston-type pump to meter the liquid. Commercially available flood-jet nozzles replaced the plastic tubes. With a flood-jet nozzle, the liquid comes out of the nozzle in a stream, then hits a hard surface to create a fan-shaped spray.

Fulgham is now retired. James Hanks, an agricultural engineer at Stoneville, continues to work with McWhorter to find the best possible application method for herbicides at low and ultra-low rates.

"This is the best system we know of to apply herbicides in oil or water at total spray volumes of less than 1 gallon per acre," says Hanks. "We started out with a rather crude sprayer system and modified it, so now it's farmer-friendly."

From 1988 to 1992, the scientists conducted field tests using ULV application. They used several different herbicides for postemergence control of johnsongrass and barnyardgrass in soybeans.

These tests show that herbicide mixed with paraffinic oil—which is similar to mineral oil—controls johnsongrass better when applied at 1 gallon per acre than it does when mixed with water and applied at 20 gallons per acre.

There may be several reasons for the increased weed control, explains McWhorter. For starters, the T-miser applies smaller, more concentrated droplets of the herbicide mixture. These droplets are more toxic to plants than the larger, less concentrated droplets dispersed in water by conventional sprayers. Oil also spreads better than water on leaf surfaces.

"Apparently, the greater spread activity leads to greater control," says McWhorter. And solubility of the herbicide in oil may also be a factor.

Overall, paraffinic oil outperformed soybean oil, cottonseed oil, No. 2 diesel fuel, kerosene, and jet A fuel as a herbicide-spreading agent.

McWhorter says ULV herbicide application is a win/win situation for everyone.

"Reduced herbicide use should improve both the farmer's bottom line and the environment," he says.

Farmers would be able to easily construct their own sprayer for ULV use. However, these low application rates are not approved by the U.S. Environmental Protection Agency.

According to McWhorter, chemical industry officials say that they plan to request registration for these extremely low application levels as new products come on the market. —By **Marcie Gerrietts,** ARS.

Chester McWhorter and James Hanks are in the USDA-ARS Application Technology Research Unit, Jamie Whitten Delta States Research Center, P.O. Box 350, Stoneville, MS 38776. Phone (601) 686-5221, fax number (601) 686-5422. ◆

Climate Change on the Great Plains

Many scientists and environmentalists expect the level of carbon dioxide (CO_2) in the atmosphere to double during the next 50 years. However, they don't know how extra CO_2 will alter global temperatures and precipitation, or which geographic areas will be most affected.

To answer these questions, ARS scientists are using complex computer models to project the many environmental interactions that determine how specific sites might respond to different climate-change scenarios.

Interpretation of these projections should allow time for farmers and ranchers in affected areas to adapt.

"For example, if climatic changes become unfavorable for livestock production in some areas of the Great Plains, ranchers can adjust the number of animals on their ranches, the time of grazing, and even the type and genetic composition of the grazing animals," says Agricultural Research Service range scientist Jon D. Hanson. "The more we know in advance about climate changes, the more we can do to prepare for them. This is especially true if we want to breed livestock or grasses with genetic traits better suited for the new environments."

In preparing for that change, Hanson and ARS ecologist Barry B. Baker are using computer models to simulate the results of various climatic shifts and the effect of these shifts on beef cattle production.

They used SPUR (Simulation of Production and Utilization of Rangeland) and CBCPM (Colorado Beef Cattle Production Model) to simulate two 30-year scenarios of how range grass and beef production would be transformed under increased CO_2 concentrations and resulting changes in climate, such as higher temperatures and increased precipitation.

SPUR simulates the response of grasses and shrubs growing in various soils. CBCPM is a cow/calf life cycle model that simulates individual animal response to changes in forage quality and quantity, as well as to changes in weather conditions. SPUR was developed by ARS, CBCPM by Colorado State University.

Scientists obtained weather data for their computer simulations by combining historical weather data from 24 weather stations, from Montana to Texas, with weather predictions from the Goddard Institute for Space Studies' General Circulation Model. The circulation model simulates potential changes in climate when concentrations of CO_2 change.

"For ranchers, the bottom line is how much beef they can produce on their ranches, either to sell or to keep as replacement stock. The range model, the beef model, and the circulation model—working together—predicted that some ranchers will benefit, and others will not, from the increased CO_2," says Baker, who coupled the SPUR and CBCPM models to produce this information at the Great Plains System Research Unit, Fort Collins, Colorado.

SCOTT BAUER

Range scientist Jon D. Hanson notes the effects of four global change scenarios on calf weaning weights and compares them with the Range Dependency Index (on the monitor) showing the percentage of a region's income that is linked to range beef production. (K4267-1)

At one simulation site near Rosebud in southeastern Montana, ranchers could expect about a 65-percent increase in forage production. Cows would use that extra forage to produce calves that weigh 6 percent more when weaned from their mothers.

On the other end of the scale, ranchers in the Texas Panhandle could expect calf weaning weights to decrease by 3 to 4 percent—despite a 9- to 12-percent increase in forage production. The researchers believe this is due to the higher summertime temperatures projected.

"Overall, effects of climate change simulated by the models were positive for sites in the Central and Northern Plains, while ranchers on the Southern Plains can expect beef production to suffer," says Baker. "However, this decrease may be overcome by using animals that are more heat tolerant."

"We chose three sites—one each in Texas, Nebraska, and Montana,—to illustrate differences from south to north. All sites experienced a temperature increase," says Hanson.

In Texas, precipitation was the same, but 11 percent more moisture evaporated from both plants and soil surfaces via evapotranspiration. Grass production increased by 18 percent, but

cattle ate 22 percent less, mainly because the forage was less digestible and the cattle suffered some heat stress. This resulted in cows weighing 12 percent less and calves 5 percent less at time of weaning.

In Nebraska, precipitation rose by 7 percent and evapotranspiration by 32, producing 27 percent more grass. The higher temperatures negated most of the beneficial effects of having more grass, so cow weights decreased by 2 percent and calf weaning weights rose only 1 percent.

In Montana, the temperature increase was welcome. It extended the length of the frost-free growing season by several weeks. Precipitation also increased by 18 percent. The total effect was a 6-percent increase in forage production, 12-percent increase in digestibility, and more favorable weather for livestock. Cattle ate 34 percent more, leading to an increased cow weight of 8 percent and calf weaning weights of 19 percent.

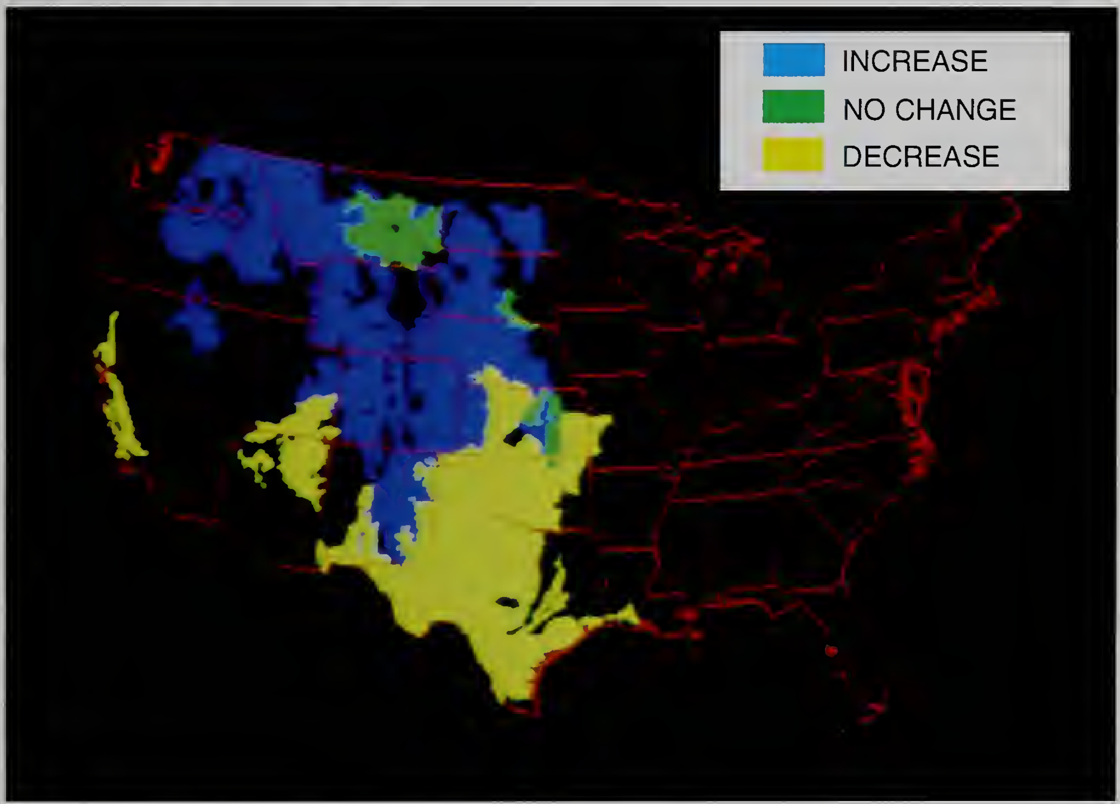
"From the perspective of any individual rancher, climate change will probably be imperceptible from the yearly variations normally encountered. Any long-term change will be gradual enough to allow for management adjustments to cope with an altered environment. For example, ranchers might include more genetic material from the *Bos indicus* species, or Brahman-type cattle. These cattle have more heat tolerance than the *B. taurus* species, which includes breeds such as Hereford and Angus. Or, ranchers might seed new grasses to take advantage of the changing weather," says Baker.

The scientists coupled these simulations with a Geographic Information System that enabled them to produce maps indicating the relative importance of global change to rural communities.

Key to calculating the impact on these communities was a Range Dependency Index that combines data from agricultural and population censuses. The index linked the importance of rangeland production to overall rural incomes in counties from the Canadian border south to the Mexican border. — By **Dennis Senft,** ARS.

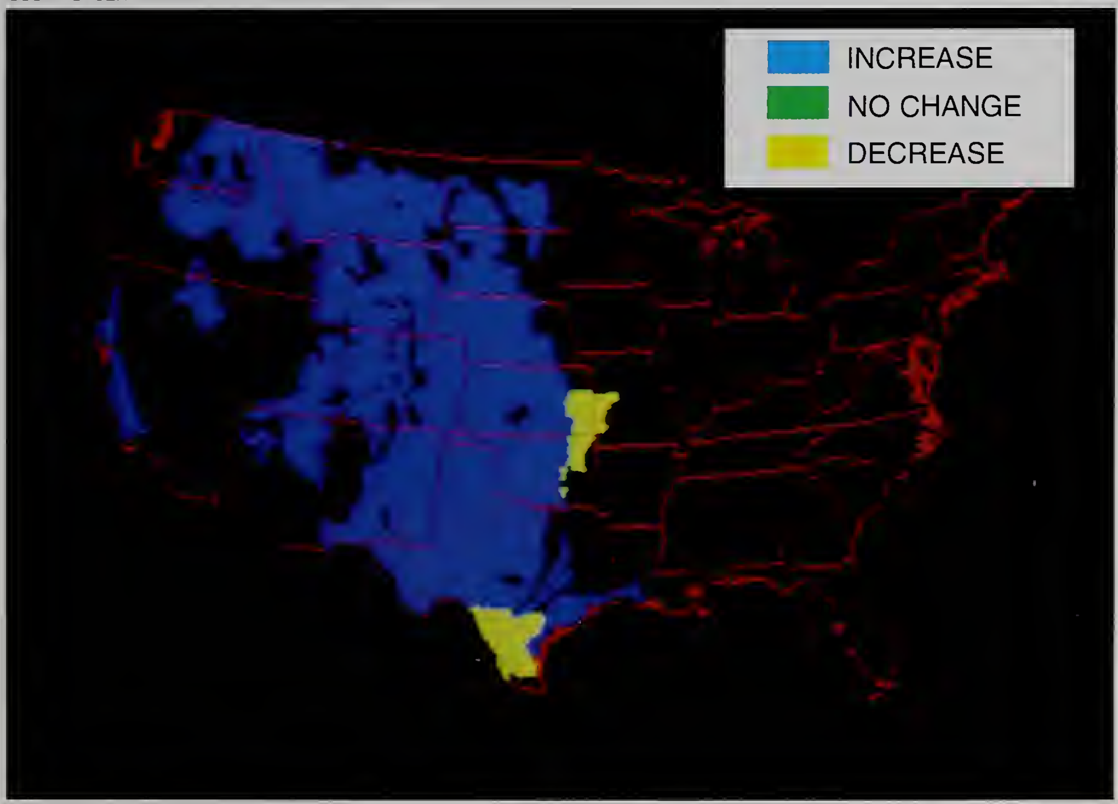
Barry B. Baker and Jon D. Hanson are in the USDA-ARS Great Plains Systems Research Unit, Natural Resources Research Center, P.O. Box E., Fort Collins, CO 80522. Phone (303) 490-8323, fax number (303) 490-8310. ◆

SCOTT BAUER



Two GIS (Geographical Information Systems) displays show how changes in CO_2, temperature, and precipitation might affect calf weaning weights (top, K4267-12) and maximum grassland production (bottom, K4267-14) at locations in the western United States.

SCOTT BAUER



Tougher Peel Repels Fruit Flies

Deceit abounds in the natural world, with protective coloration—exterior camouflage—perhaps the most obvious example. Many species of insects, fish, and other creatures are disguised so they appear nearly invisible to their predators.

But Agricultural Research Service entomologist Patrick D. Greany and a group of colleagues are pursuing another kind of natural trickery. They are trying to arrest aging and softening of citrus peels and keep them impenetrable to egg-laying fruit flies.

If successful, the ARS team may eventually offer citrus growers a gentle, naturally derived measure to prevent fruit fly infestation. It could also alleviate the possible loss of malathion, which is now undergoing review by the U.S. Environmental Protection Agency.

And citrus growers would breathe a sigh of relief to have another suitable alternative to help protect a citrus export industry in Florida worth $100 to $200 million annually.

Some years ago, Greany got the idea to try gibberellic acid (GA) as a fruit fly defense after another scientist demonstrated that the compound reduces postharvest decay in oranges. "I thought if it works against molds, maybe it will work against fruit flies, because both are best able to attack late season fruit," he says.

Greany, based in Gainesville, Florida, and researchers at three other ARS installations are looking at several aspects of this use of GA.

Ten years of research have led the scientists to one conclusion: By treating citrus fruit with this natural plant growth-regulating hormone, a citrus peel stays youthful—green, firm, and unappealing to Caribbean, Mediterranean, Mexican, and Queensland fruit flies. "Females looking for a place to lay their eggs respond to the yellow color of a grapefruit," says Greany. But if the peel is green, most females bypass it altogether.

That's the trick: Outside, fruit flies encounter a green, firm, and unyielding peel, so they usually don't even bother trying to lay eggs.

But inside, treated fruit is fully ripe, juicy, and sweet—perfect for juicing or eating.

KEITH WELLER

Caribbean fruit flies demonstrate a preference for an untreated, yellow-skinned grapefruit versus the gibberellic acid-treated green one in the background. Both are fully ripe. (K4632-2)

"Gibberellic acid treatment has no adverse effect on the internal ripening of the fruit," Greany says.

What Does Gibberellic Acid Do?

Occurring naturally in growing plants, GA is commercially derived from a fungus called *Gibberella fujikuroi.* This growth hormone—produced by Abbott Laboratories and sold as ProGibb—has been safely used for more than 40 years as a growth regulator on citrus and about three dozen other crops.

Grape growers use GA to increase the size of their fruit. [For use of gibberellic acid on rice, see *Agricultural Research,* August, 1992, pp. 10-12.]

Citrus growers are using GA to extend the harvest season and to improve shipping quality, because it keeps the peel tough and resistant to postharvest molds and mechanical injury.

A grower's cost to treat with GA to control fruit flies would be roughly comparable to the cost of using malathion. By spraying GA on the trees just before citrus turns from green to orange or yellow, says Greany, citrus growers can also "extend by at least 2 months the fruit's inherent resistance to fruit flies." In Florida, this color change, called colorbreak, occurs around September in untreated fruit.

Unripe citrus peels resist insect attack in three ways, explains Greany: first, by the built-in repellancy of the green color; then, by an unyielding firmness that discourages female flies from laying eggs in the fruit.

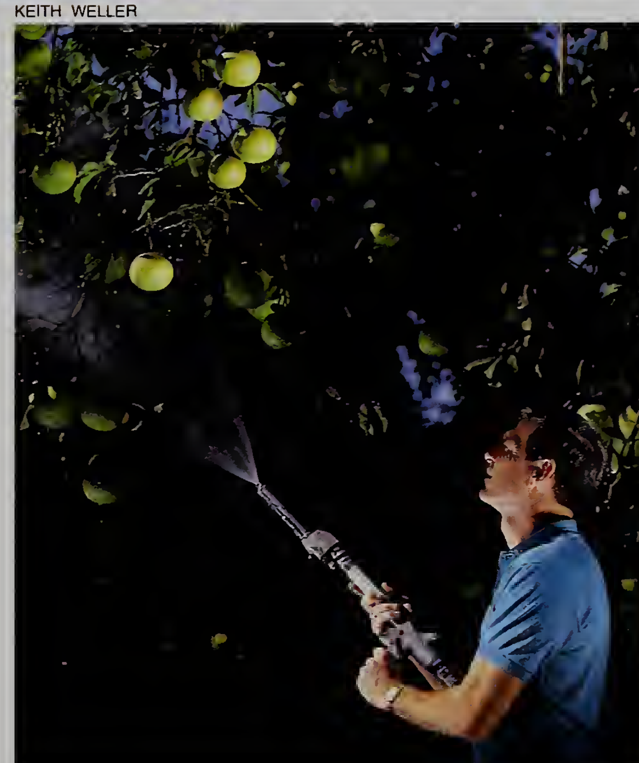
Should these two defenses be overcome and eggs deposited, the third line of defense kicks in: peel chemicals—allelochemicals—such as peel oils, that are naturally toxic to larvae. Most larvae that manage to hatch in the peel and begin eating their way through it never make it inside to the important part of the fruit.

But as the fruit ripens, the peel changes color, softens, and—as ARS chemist Philip E. Shaw at Winter Haven discovered—the chemicals responsible for resistance begin to dissipate. Of course, this leaves the fruit vulnerable to attack.

Shaw found that the allelochemicals decline, even with GA treatment. But the GA-toughened peel traps any hatched larvae for a longer time in the region where the allelochemicals occur, so the larvae die, even though the chemicals are less abundant.

KEITH WELLER

KEITH WELLER



Near the Kennedy Space Center, fruitfly-filled field cages surround grapefruit trees that have been treated with 10 ppm gibberellic acid. (K4626-6)

Inset: Horticulturist Roy McDonald sprays gibberellic acid on grapefruit prior to placing cages over them. (K4629-19)

In field-cage tests conducted by Greany in Florida in cooperation with horticulturist Roy E. McDonald and entomologist William J. Schroeder of the U.S. Horticultural Research Laboratory in Orlando, grapefruit treated with GA had up to 90 percent fewer Caribbean fruit flies than untreated fruit.

Although it doesn't cause significant yield loss in our citrus, the caribfly is what's called a quarantine pest—that is, other countries and states that don't want the fly—but do want our fruit—require U.S. growers to have their fruit certified fly-free.

The major reduction in infestation that GA provides could assist in qualifying citrus for fly-free certification, Greany says.

Japan alone annually imports 11 million cartons—more than $100 million worth—of U.S. grapefruit. And Florida grapefruit are also shipped to many other states and countries where caribflies aren't wanted.

KEITH WELLER

Elaine Boyd, marketing director for the Specialty Chemical Division of Union Carbide, and ARS entomologist Patrick Greany compare gibberellic acid-treated (green appearing) with untreated grapefruit. Boyd supplied the wetting agent used in the experimental spray. (K4628-12)

Fly-Free Certification

Growers exporting citrus from Florida to quarantine-sensitive destinations must get fly-free certification from the Florida Department of Agriculture and Consumer Services. Because of citrus' potent natural fly resistance, early-season fruit (shipped before December 20) is required to meet a less stringent protocol to be certified fly-free than does fruit shipped after that date.

Certification can be obtained currently in any of several ways, but all the methods have their problems.

About half of all citrus for export is certified fly-free by maintaining a production area free of Caribbean fruit flies. Most growers spray their groves with a mixture of a yeast-derived attractant and malathion. A downside to this technique: The attractant lures beneficial and other nontarget insects as well as fruit flies. And importing countries won't accept the fruit if malathion residues are too high. But no alternative preharvest treatment is yet available.

Growers can also help maintain a fly-free area by mechanically removing other plants the flies feast on—such as wild guava—from a wide radius of the grove. Removing these host plants can be costly. So growers wanting to use this method must have at least 40 acres of groves to make it cost effective.

Up to 85,000 acres of citrus groves located near residential areas cannot obtain fly-free certification at all because guava is a very common ornamental plant.

For those growers, postharvest treatment is an option. They can ship fruit to Japan if the fruit is held for specified times at temperatures below 35°F, which kills any flies present. But cold treatment can—if not done properly—soften and blemish fruit peels, making the citrus less salable. And cold-treating fruit during shipment is costly.

Another alternative for growers is fumigation of harvested fruit with methyl bromide—a chemical that may damage the fruit and is currently being challenged because of concern about its possible effect on the ozone layer.

How's GA Applied?

ARS scientists have worked out how much GA growers would need to spray on their trees and when it should be applied. It's mixed with a surfactant that helps it enter the citrus peel.

Surfactants that have been used include Triton B 1956 or X-100. But Greany found that by using another brand, Silwet L-77, a grower could apply five times less gibberellic acid and still get the same results. The most cost-efficient and effective recipe: 10 parts per million GA plus 0.1 percent

Silwet L-77, sprayed just before colorbreak.

The surfactant, Greany found, also gets GA into the fruit faster, so the treatment begins to work immediately.

Union Carbide, the company that manufactures Silwet L-77, and Abbott Laboratories have provided Greany with ample supplies of the surfactant and GA, respectively.

Citrus lovers who are repulsed by the thought of green citrus with firm peels, take heart. Studies by Charles Coggins of the University of California, Riverside, as well as by Greany and collaborators in Florida and Brazil, have shown no significant difference in the internal state of the fruit. Whether treated or untreated, the fruit's appearance, texture, and flavor were identical.

And to get rid of the green, growers could simply expose the fruit to ethylene gas, a natural, EPA-registered, commercially available ripening agent, to bring the fruit to its normal color. "This is only a concern for fruit going to the fresh market," Greany says. Most U.S. oranges and half of our grapefruit are destined to become juice; for those, peel color is irrelevant.

"Of course you can't keep the fruit resistant to fruit flies forever," Greany admits. But growers may be able to protect it through the end of February, and "most of the fruit is shipped by then. If importing countries determine that this treatment provides quarantine security, it would be a big boon to the Florida citrus industry."

If and when the treatment goes into effect as a certification procedure, Greany and McDonald envision that the Florida Department of Agriculture could assess peel characteristics to determine a fruit to be fly-free. They are working out ways to measure those characteristics now.

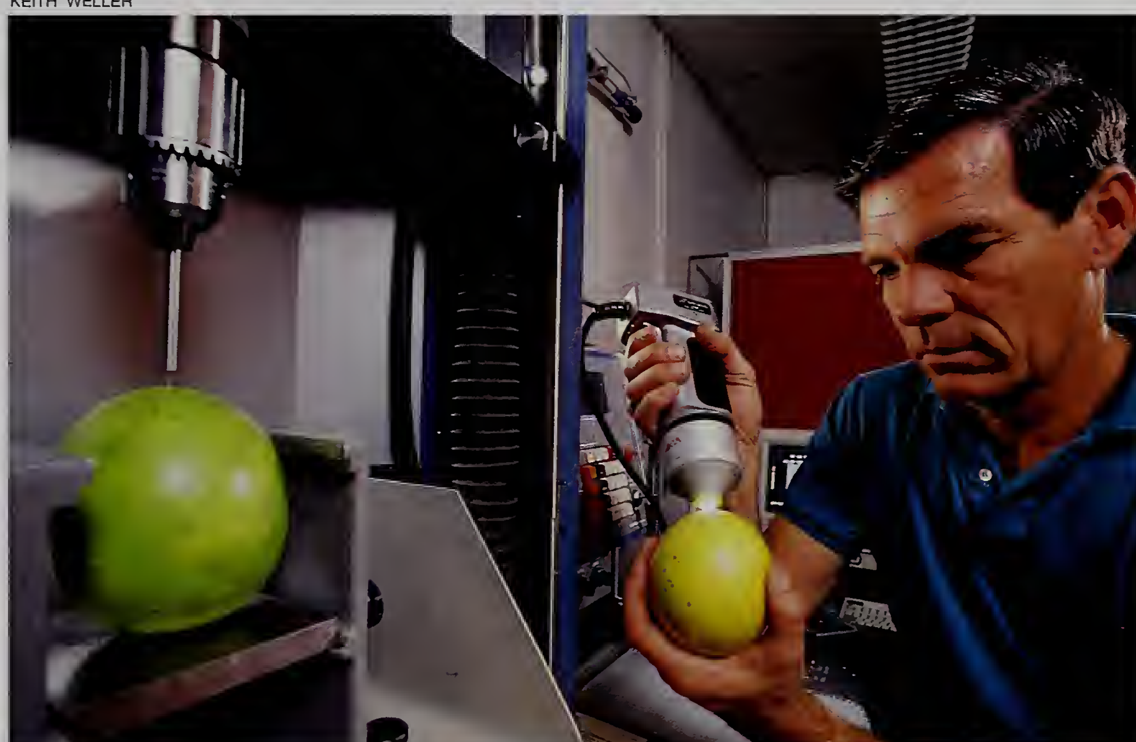
"We have portable devices to measure peel color and puncture resistance," Greany says. And Shaw measures a chemical called limonin in resistant citrus each season. He quantifies how much of the chemical a peel should have to be considered fly resistant. Says Shaw, "We haven't proved that the limonin is the reason the fruit fly won't attack treated fruit as early as it will untreated, but it's our theory right now because limonin is a known antifeedant for other insects."

Biophysics Research Unit at Gainesville, the device may be a suitable nondestructive means of detecting pests in citrus fruits.

Entomologist Carrol O. Calkins and Dennis Shuman, an agricultural engineer, will carry out a 3-year study to determine its efficacy.

Says Greany, "We want to develop a totally field-oriented approach that can be used to determine fly resistance."

KEITH WELLER



A pressure tester measures peel puncture resistance (left, foreground) while horticulturist Roy McDonald checks peel color with a chromameter. The information can be used to forecast how susceptible grapefruit will be to fruitfly egg laying. (K4627-2)

If limonin proves to be a fruit fly antifeedant, the ARS workers will try to develop a portable, instant, easy test that officials could use to measure the limonin content and peel oil levels.

An alternative method for spotting the incidence of insect pests in fruit—and thereby confirming the effectiveness of GA treatment—might be to use a portable "acoustic detector" capable of picking up the faint sounds of chewing insects.

Developed in 1989 by J.C. Webb and colleagues in the ARS Behavior and

Checking GA Treatment Out

ARS awarded Greany and colleagues funds for a full-scale pilot test in Florida and Mexico to test GA treatment against Caribbean and Mexican fruit flies. The 3-year pilot project, beginning this season, will test how well GA treatments work in actual field conditions. The Mexican tests will be conducted with Martin Aluja of the Instituto de Ecologia, A.C., in Veracruz.

In addition, the ARS team is collaborating with Aldo Malavasi of the University of Sao Paulo, Brazil, in hopes of making oranges less susceptible to Mediterranean and South American fruit flies. This work is supported by a United States/Brazil Science and Technology Initiative under the auspices of the Office of International Cooperation and Development.

Past collaborations in Israel supported by the Binational Agricultural Research and Development fund also showed the effectiveness of GA treatments against the Mediterranean fruit fly in oranges and grapefruit. And collaborative tests in Australia have shown promising results of GA against the Queensland fruit fly.

This research could be useful to U.S. agriculture by showing that GA treatments work against these other serious citrus pests. The technology could be applied, should the pests ever be accidentally introduced—despite major efforts by USDA's Animal and Plant Health Inspection Service (APHIS) and state regulatory agencies to prevent their entry.

The Florida Caribbean Fruit Fly Technical Committee evaluates methods of fruit fly control for Florida fruit destined for export. After conducting evaluations, the committee recommends to APHIS those treatments that seem worthy of including in the fly-free certification program.

The chairman of that committee, Connie Riherd, says, "I feel confident that once we have the data from the pilot project, we would be ready to propose to APHIS that they include this certification procedure in their next bilateral trade talks with Japan."

Summing up the expectations surrounding the GA work, Riherd says, "The technical committee and the citrus industry are very interested in this work. We would like to see this implemented as soon as possible."

Some of the benefits of GA treatment are obvious: less environmental concerns about fumigants and residue-free citrus for consumers in other states and countries.

Benefits Galore

Some of the benefits of GA treatment are obvious: less environmental concerns about fumigants and residue-free citrus for consumers in other states and countries.

The GA treatment would give growers in any state a biologically compatible treatment they could implement immediately, should the Mediterranean fruit fly ever again become established in the mainland United States.

For growers who use postharvest disinfestation techniques, each month that GA treatment can keep fruit resistant will save growers at least $15 million, according to Sam Simpson, the former administrator of the Caribbean Fruit Fly Protocol.

The treatment brings some extra, less obvious, benefits. Treating with the growth regulator automatically strengthens citrus against postharvest plant diseases. And since the only organisms affected by the treatment are pests of citrus, beneficial organisms that attack citrus pests are spared. Honey bees that are important in citrus pollination won't be killed, as they can be by malathion spray.

Further, the fly-free zones—and hence, the citrus export market—could possibly be expanded. So even those unfortunate growers who live near wild guava could receive fly-free certification—provided they treat their groves with gibberellic acid.

The scientists are highly hopeful that their pilot project will lead to widespread use of the new technology.—By **Jessica Silva,** formerly with ARS.

Patrick D. Greany is at the USDA-ARS Insect Attractants, Behavior, & Basic Biology Laboratory, P.O. Box 14565, Gainesville, FL 32604. Phone (904) 374-5763, fax number (904) 374-5781. Philip E. Shaw is at the USDA-ARS Citrus & Subtropical Research Laboratory, P.O. Box 1909, Winter Haven, FL 33880. Phone (813) 293-4133, fax number (813) 299-8678. Roy E. McDonald is at the USDA-ARS U.S. Horticultural Research Laboratory, 2120 Camden Rd., Orlando, FL 32803. Phone (407) 897-7324, fax number (407) 897-7309. ◆

Rock Phosphate—Rx for Poor Soils

The answer to what ails many soils in the Appalachian region may lie conveniently in a material that is mined in nearby North Carolina.

ARS soil scientists, Robert J. Wright and V.C. Baligar, have found that Carolina rock phosphate can partially ameliorate the acid soils that make it difficult to grow many crops in Appalachia. Acid soils are very common in the eastern United States.

Phosphorus is a major nutrient limitation to successful forage production, but many farmers can't afford the commercial fertilizer and lime additions generally recommended for pasture improvement.

Baligar, at Beckley, West Virginia, says commercial phosphorus is more expensive than rock phosphate because the raw rock has to be processed into a soluble form that roots can take in. But when the raw rock is applied to highly acid soils, the acidity causes the rock to dissolve.

Wright, formerly at Beckley and now at Beltsville, Maryland, says that within 30 days, dissolution of North Carolina rock phosphate in soil raises pH slightly and increases the availability of calcium and phosphorus to roots, while decreasing the toxicity of aluminum. The result is better root growth and improved water and nutrient use in infertile acid soils.

Ironically, North Carolina rock phosphate was once sold only overseas. In the past, Appalachian farmers tried other types of rock phosphate, without success, because it didn't dissolve fast enough to meet demands of growing crops—particularly corn and other row crops.

Wright and Baligar conducted laboratory tests and greenhouse experiments to determine the solubility and fertilizing effectiveness of North Carolina rock phosphate in acid soils common to Appalachia. They found that it was almost as effective as commercial fertilizer and also resulted in better root growth.

Field tests are being conducted in southern West Virginia to determine the long-term effect of rock phosphate application on soil properties and the growth of grasses and legumes.

The tests should also determine if rock phosphate can reduce the need to lime Appalachian pastures.—By **Don Comis,** ARS.

V.C. Baligar is at the USDA-ARS Appalachian Soil and Water Conservation Research Laboratory, P.O. Box 867, Beckley, WV 25802-0867. Phone (304) 252-6426, fax number (304) 253-7705. Robert J. Wright is at the USDA-ARS Environmental Chemistry Laboratory, Bldg. 001, 10300 Baltimore Ave., Beltsville, MD 20705-2350. Phone (301) 504-6511, fax number (301) 504-5048. ◆

New Cayenne Pepper Available

SCOTT BAUER

Charleston Hot peppers. (K5047-16)

A new cayenne pepper ideal for home gardeners who want a compact, high-yielding variety for their chili and other spicy foods has been released by the U.S. Department of Agriculture.

Named Charleston Hot, the new pepper is also resistant to all four known races of southern root knot nematode and to other nematode species.

The southern root knot nematode damages plant roots, cutting yields by up to 50 percent and killing a plant under extreme conditions, says Philip D. Dukes, a plant pathologist with the Agricultural Research Service in Charleston, South Carolina.

Dukes says Charleston Hot reduced root knot nematodes by 95 percent in field trials.

"Home gardeners will like this new variety because it doesn't take up as much space as other cayenne pepper varieties," says Dukes. "It only grows to about 18 inches high. It's also colorful and produces excellent yields of about 2 pounds of fresh peppers per plant. We think it will appeal to commercial growers."

Dukes and ARS plant geneticist Richard L. Fery, at the agency's U.S. Vegetable Laboratory in Charleston, developed the new variety after more than a decade of pepper research.

Charleston Hot is a sister line of another cayenne pepper called Carolina Cayenne, also developed by Fery, Dukes, and Roy Ogle of Clemson University.

Charleston Hot has an unusual trait for a cayenne pepper: It changes through a rainbow of colors as it ripens. The pepper starts out yellow-green—the color of the plant foliage—and changes to golden yellow, bright orange, and then to a deep red when it matures.

At maturity, a Charleston Hot pepper is about 4 inches long—and, as its name implies, it's very hot—making it ideal for highly spiced dishes, Dukes says. One plant will produce at least 134 to 150 pepper pods, or about one-half pound of dried peppers.

Charleston Hot can be grown almost anywhere in the United States. Dukes says limited amounts of seed are available to breeders and gardeners by writing to him at the U.S. Vegetable Laboratory.—By **Sean Adams,** ARS.

Philip D. Dukes and Richard L. Fery are at the U.S. Vegetable Laboratory, 2875 Savannah Highway, Charleston, SC 29414-5334. Phone: (803) 556-0840, fax (803)763-7013. ◆

SCOTT BAUER

Beneficials Are Money in the Bank

There are lots of insects in Benny Johnston's cottonfields in south Georgia, but that's fine with him.

Johnston and other farmers are beginning to realize that many of the insects that call his cottonfields home are actually beneficial, because they attack insect pests that damage his cotton. So he's willing to minimize his use of chemicals, allowing the beneficials, as he affectionately calls them, to protect his crop.

"I think cotton growers realize this is the way to go," says Johnston, who farms 600 acres of cotton in Tift County. "We've got to give the good insects a chance. It's catching on."

Taking advantage of beneficial insects is catching on for many reasons—primarily because of the high cost of chemicals and increasing insect resistance to them.

Also, populations of beneficial insects blossomed because of the Boll Weevil Eradication Program, which eliminated the pest in the Carolinas and has been extended into Georgia, southern Alabama, and Florida.

Parasitic wasp at top of container in foreground is about to head for cotton plants entomologist Joe Lewis is positioning in this laboratory wind tunnel. Designed to simulate outdoor conditions of about a 1 mile per hour breeze, the tunnel is used to determine the wasp's response to chemical attractants given off from caterpillar-damaged plants. (K5036-12)

Farmers no longer have to spray to control the weevil—so those chemicals don't kill the nonpest insects. Farmers are beginning to realize that chemicals not only kill the bad guys—corn earworms (a.k.a. cotton bollworm and tomato fruitworm) and other crop pests—but also the good guys, such as parasitic wasps and other beneficials that attack the bad guys.

It's not surprising, then, that parasitic wasps have gotten a lot of attention from ARS scientists. Researchers in Tifton, Georgia, and Gainesville, Florida, have focused on two wasps—*Cotesia marginiventris* and *Microplitis croceipes*—as being among the most beneficial of the beneficials.

They're valuable because of the crop pests they attack. *M. croceipes* seeks out corn earworms and other insects in what is known as the *Heliothis/Helicoverpa* group of insects. It's one of the most damaging insect groups worldwide, costing growers $2 billion each year in control costs and yield losses to cotton, corn, soybeans, lettuce, tomatoes, and other crops. *C. marginiventris* targets a broader range of pests—about 20, such as noctuids, which include the fall armyworm, the beet armyworm, and the cabbage looper. The beauty of using parasitic wasps is that they only attack the targeted pest—not people, animals, valuable crops, or other beneficial insects such as honey bees.

It's a complex ecosystem in cottonfields like Benny Johnston's, with the wasps being among many insects searching for food and a chance to reproduce. ARS scientists W. Joe Lewis, James Tumlinson, and colleagues Gary E. Herzog and William A. Lambert at the University of Georgia, have come a long way toward understanding these wasps.

Lewis is an entomologist at the Insect Biology and Population Management Research lab in Tifton, Georgia, while Tumlinson is a chemist and also in charge of the Insect Attractants, Behavior, and Basic Biology Research Laboratory in Gainesville, Florida.

They're part of research teams that have spent years studying these wasps—everything from their flight paths, to the chemicals in caterpillar feces that attract the wasps, to the caterpillar spit that sets off plant self-defense mechanisms. They've studied the wasps' behavior in the field and in laboratory wind tunnels designed to simulate outdoor conditions.

SCOTT BAUER

A female wasp (bottom, left) homes in on a corn earworm. (K5035-17)

Lewis calls the interactions between the wasps, their hosts, and plants a cat-and-mouse game, governed largely by an intricate mix of chemical scents. It begins when the caterpillars feed on the plant, which gives off distress chemicals—including a special group of compounds called terpenoids—signaling that it's under attack. These act as beacons for the wasps, which home in on those chemicals to find the caterpillars.

The scientists, along with Gainesville entomologist Ted Turlings, have identified these signaling compounds. They have found, for the first time, that the entire plant—not just damaged leaves—gives off chemicals when it's under attack. Parasitic wasps are also attracted by the feces of feeding larvae—lured by undigested plant material and other substances in the larval waste.

When a female wasp locates the caterpillar, it attacks and lays a single egg inside. The researchers have found that the female also marks the caterpillar with her own chemical scent, so that later—if she returns to the same area—she'll pass over any caterpillar she's already parasitized. "That's because only one newborn wasp can survive per caterpillar—so she'd be wasting her time by laying more than one egg in the same caterpillar," Lewis explains.

She's particular about where she lays her eggs. Her first choice is a caterpillar that hasn't been parasitized. Her second choice is a caterpillar that's been attacked by another female wasp (each female wasp's scent is different).

As a last resort, she'll lay a second egg in a host she's already parasitized. The female wasp also senses that a caterpillar has been parasitized because the caterpillar feeds less and produces less feces, so its attractive odor is diminished.

Once the wasp egg is inside the caterpillar, it hatches within a few days into a larva and begins to feed on blood and fat, eventually taking over the insect "like a cancer," Lewis says. The invaded caterpillar doesn't eat as much, and is unable to reach the pupal stage—the point at which it prepares to become a moth and begin a new life cycle. Meanwhile, the parasite larva eats its way out of the caterpillar and spins its own cocoon—*M. croceipes* in the soil, *C. marginiventris* on the plant leaf. From egg to adult, the cycle takes about 2 weeks.

Lewis estimates that a farmer like Benny Johnston should maintain

between 300 and 600 female wasps per acre to have a healthy natural population. In field studies, Lewis says, 80 to 100 percent of moth larvae have been parasitized with 500 females per acre. To monitor wasp populations in the field, the researchers are developing a prototype trap containing a mixture of plant and caterpillar chemicals that will attract wasp females. Scientists are working on ways to mass-rear the wasps to boost natural populations if the traps show that such a release is necessary.

Tumlinson and other scientists have the tricky job of isolating, identifying, and synthesizing the chemicals involved in the cat-and-mouse game—and studying how the chemicals affect wasp behavior.

He and Turlings have discovered that once a caterpillar begins feeding on a plant, such as a corn seedling, the plant mobilizes its defenses, emitting chemical distress signals that help lure parasitic wasps to their prey.

"We've even used caterpillar spit to induce that response in plants that have been artificially wounded," says Tumlinson. They've studied the chemicals given off by cotton, corn, soybeans, and cowpeas. Each has its own blend of chemicals that lures the wasps to the rescue. By understanding these processes, it may be possible to breed varieties of crop plants that are more effective at recruiting the beneficial wasps.

They've also found that the wasps raised in the laboratory learn these chemical cues—and can actually be trained to respond to the smell of unrelated substances such as vanilla. Associative learning, as it's called, is important because wasps reared in the laboratory have to be trained to zero in on the right caterpillar and host-plant chemicals. Otherwise, if released in the field, Lewis says, "they might just fly off and not be able to locate the targeted pest."

That would be bad for Benny Johnston and Bob McLendon, another farmer in Georgia who has worked with Lewis on field studies of beneficial insects. McLendon farms about 2,600 acres in Calhoun County, including 700 acres of cotton, and has been active in the Southern Cotton Growers, Inc., which represents growers in Alabama, Florida, Georgia, the Carolinas, and Virginia. He, Johnston, and Lewis cite

SCOTT BAUER

The wasp attacks a caterpillar, laying a single egg inside and marking the caterpillar with her own chemical scent. (K5035-20)

the Boll Weevil Eradication Program as a key factor in the reemergence of beneficial insects.

That program, which began in 1978 on a trial basis in North Carolina, has wiped out the weevil in the Carolinas and has virtually eliminated the pest on 578,000 acres in Georgia, southern Alabama, and Florida. McLendon says it's had a ripple effect: Because chemicals are no longer needed to control the boll weevil, he now applies far less chemicals to control *Heliothis* and *Helicoverpa* pests.

"We've seen a tremendous reduction in spraying for these pests because beneficial populations are so high," he says, noting that he's reduced chemical applications from 18 to as few as 5 or 6 on his cottonfields. "I made the cheapest cotton crop I've ever grown this year," he said, primarily because of savings from reduced pesticide use.

One insect the wasps have helped control is the beet armyworm, which became a serious problem in Georgia cottonfields in 1988 and 1990.

Boll weevil chemicals were still being applied then, and the beet armyworm flourished in the absence of its natural enemies.

But this year, Lewis says, it was generally held in check by the parasitic wasps. From 50 to 80 percent of the beet armyworms killed in 1992 in Georgia cottonfields were parasitized by beneficial insects, with *C. marginiventris* the most prevalent, Lewis estimates. McLendon says that has been critical because there are no insecticides that effectively control the beet armyworm.

McLendon and Johnston don't know all the intricacies of the cat-and-mouse games taking place in their fields, but they are committed to letting those games take place. As businessmen, they realize that the beneficials are a good investment. As McLendon says, "We don't understand everything about how the wasps work, but I can understand more money in the bank."—By **Sean Adams**, ARS.

W. Joe Lewis is at the USDA-ARS Insect Biology and Population Management Research Laboratory, Tifton, GA 31793. Phone (912) 387-2369, fax number (912) 387-2321. James Tumlinson and Ted Turlings are at the USDA-ARS Insect Attractants, Behavior and Basic Biology Research Laboratory, Gainesville, FL 32604. Phone (904) 374-5730, fax number (904) 374-5781. ◆

Science Update

Before dying in a Stalinist labor camp in January 1943, Soviet botanist Nikolai I. Vavilov created a germplasm bank in what is today St. Petersburg, Russia. ARS recently funded an English translation of Vavilov's papers. His "heresy"—a scientifically sound theory that the region of a species' widest genetic diversity represents its geographic center of origin—still guides the search for useful crop-plant germplasm. ARS' National Small Grains Collection in Idaho has about 400 barley and wheat accessions collected long ago by Vavilov. In October 1992, ARS signed a dozen new research accords with Russian and Ukrainian scientists, including ARS help to computer-catalog the Vavilov Institute's 350,000 accessions. *Henry Shands, National Program Staff, Beltsville, MD. Phone (301) 504-5059.*

• • •

DAVID NANCE

Russian wheat aphids. (K3656-3)

The year after Vavilov died, the United States acquired a very important wheat accession from the Soviet Union—but no one knew it at the time. Now, ARS has used it to develop the first breeding line of hard red winter wheat that resists the Russian wheat aphid. Since invading in 1986, the aphid has rocked the farm sector for an estimated $645 million in pesticide costs, yield damage, and related losses to local economies. The new breeding line is set for release this year. *Cheryl A. Baker, Plant Science Research Laboratory, Stillwater, OK. Phone (405) 624-4251.*

• • •

Researchers have grown high-quality hydroponic lettuce and strawberries with waste water from rainbow-trout ponds. Hydroponic crops may lift farm aquaculture's potential—by making a virtue out of the necessity to control waste from fish ponds. *Fumiomi Takeda, Appalachian Fruit Research Station, Kearneysville, WV. Phone (304) 725-3451.*

• • •

A public/private consortium—Biotechnology Research and Development Corp. of Peoria, Illinois,—has a license to produce ARS-invented granules of cornstarch-encapsulated pesticides that will stick to plant leaves. The technology includes a formulation, using bacteria that kill corn borers, developed under a cooperative research and development agreement with the consortium. *Michael R. McGuire, Plant Polymer Research, Peoria, IL. Phone (309) 685-4011.*

• • •

A weevil from Australia is the first natural enemy imported to help save the Everglades from the melaleuca tree, another Australian native. The weevil feeds on branch tips of melaleuca, destroying its ability to make flowers and seeds. In a quarantine lab, scientists are further gauging the weevil's potential. Melaleuca may already cover 1.5 million acres in the Everglades, crowding out native swamp plants. *Ted Center, Aquatic Plant Management Laboratory, Fort Lauderdale, FL. Phone (305) 475-0541.*

• • •

A new species of a tiny, wormlike creature known as a nematode uses bacterial "chefs" to prepare its meals of crop-damaging caterpillars. *Steinernema riobravis* nematodes wiggle into a caterpillar, let loose bacteria that kill it in a day or two, then eat it. *Helicoverpa zea* caterpillars damage corn, cotton, tomatoes, and other crops to the tune of over a billion dollars a year. *Jimmy R. Raulston, Subtropical Cotton Insects Research, Weslaco, TX. Phone (512) 969-4807.*

• • •

ARS and Mexican scientists have begun work on a fast field test needed by ranchers to learn if cattle are infested with disease-causing ticks that resist organophosphate pesticides. Some populations of southern cattle ticks have become resistant to these chemicals—the only ones approved for dipping cattle in a 700-mile quarantine zone along the Texas-Mexico border. Keeping resistant ticks from escaping the zone protects the U.S. cattle industry from multimillion-dollar losses from cattle tick fever. *John E. George, Tick Research, Kerrville, TX. Phone (512) 792-0338.*

• • •

Speaking of parasites: Mites that feed on chicken blood put an $80 million bite on U.S. egg producers. But ARS researchers found that extracts from peppermint and other plants deter the pests—northern fowl mites—from feeding. *John F. Carroll, Livestock Insects Laboratory, Beltsville, MD. Phone (301) 504-9017.*

U.S. Department of Agriculture
Agricultural Research Service
Room 318, B-005, BARC-West
10300 Baltimore Ave.
Beltsville, MD 20705-2350

To stop mailing ______________ ☐
To change your address __________ ☐
Please return the mailing label from this magazine.

Superintendent of Documents Subscription Order Form

Order Processing Code:

6130

Charge your order. It's Easy! MasterCard VISA

To fax your orders (202) 512-2233

☐ **YES**, enter my subscription as follows:

___subscriptions to **AGRICULTURAL RESEARCH** for $28.00 per year ($35.00 foreign).

The total cost of my order is $__________. Price includes regular domestic postage and handling and is subject to change.

Call Order and Information Desk at (202) 783-3238 after 3/31/93 to verify prices.

(Company or personal name) (Please type or print)

(Additional address/attention line)

(Street address)

(City, State, ZIP Code)

Daytime phone including area code)

(Purchase Order No.)

YES NO

May we make your name/address available to other mailers? ☐ ☐

Please choose method of payment:

☐ Check payable to the Superintendent of Documents

☐ GPO Deposit Account ☐☐☐☐☐☐☐–☐

☐ VISA or MasterCard Account

☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

☐☐☐☐ (Credit card expiration date)

Thank you for your order!

(Authorizing Signature)

Mail To: New Orders, Superintendent of Documents
P.O. Box 371954, Pittsburgh, PA 15250-7954